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AUTOMATIC FLIGHT MANAGEMENT SYSTEM FOR HELICOPTERS

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AUTOMATIC FLIGHT MANAGEMENT SYSTEM FOR HELICOPTERS

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Abstract

The Automatic Flight Management System (AFMS) is an integrated digital avionics system developed for advanced helicopters. Its purposes are the reduction of crew work load and to insure safety of flight especially during low altitude flight at night.

To achieve these purposes, it provides the following functions.

1) Automatic flight control
2) Flight monitoring
3) Voice warning/announcement
4) Integrated flight data display
5) Integrated NAVCOM equipments control

1. Introduction

The Automatic Flight Management System (AFMS) is the integrated digital avionics system and has been developed by Mitsubishi Heavy Industries,Ltd.(MHI). Its purposes are the reduction of crew work load and to insure safety of flight especially during low altitude flight at night. This system was named AFMS (which is the synthetic word combining AFCS and FMS) because it combines functions of Flight Management System (FMS) with functions of Automatic Flight Control System (AFCS) to achieve these purposes.
This system has been completely flight tested.

This paper will describe the primary functions and system architecture of the AFMS.

2. General description of the system

2.1 Primary functions of the AFMS

The AFMS has the following primary functions.

(1) Automatic Flight Control

The AFCS functions consist of the three-axis SAS function and many of the four-axis autopilot modes.
A distinctive feature is the automatic flight modes where flight can be accomplished without any steering actions by the pilots between hovering at one location, and moving to a hover at a remote location.

(2) Flight Monitoring

Calculation and the displaying of flight performance data, and automatic monitoring of operational limitations.

(3) Voice warning/announcement

Voice warnings in the event of engine failure etc. and announcements such as the arrival at way points are provided.

(4) Integrated display of flight data

Versatile flight data is displayed on the EHSI (Electronic Horizontal Situation Indicator), and automatic changes of display modes coupled with AFCS functions are available.

(5) Integrated control of NAVCOM equipments

Integrated control ability of NAVCOM is involved in its CDU (Control Display Unit)

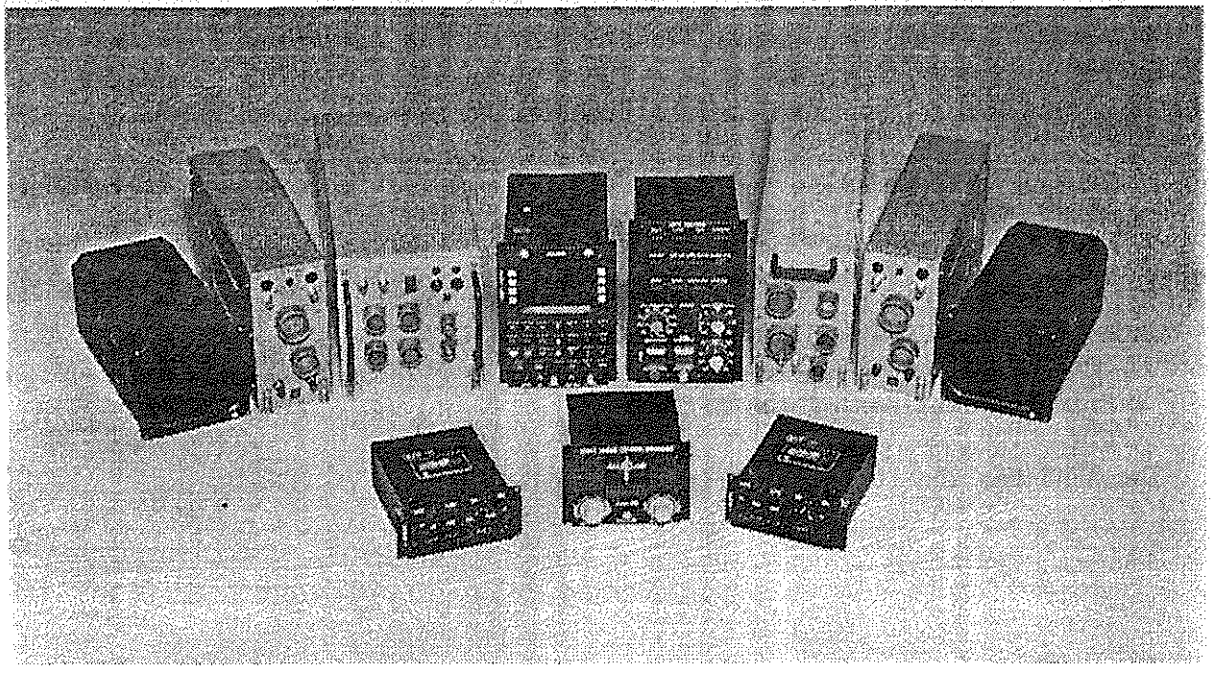

Fig. 1. AFMS components

2.2 System equipments

The AFMS is composed of the following equipments. (shown in Fig. 1)

(1) AFCS subsystem

-- An AFCS Computer,
This single digital computer is comprised of the processing unit and flight control servo electronics. It plays the primary role for AFCS functions.

-- An AFCS Control Panel
This unit includes mode switches and hover height and ground speed setting knobs for the Approach/Hover modes.

(2) Management subsystem

-- An AFMS Control and Display Unit (AFMS CDU),
This equipment is the primary man/machine interface of the AFMS. It includes function switches and a monochrome CRT indicator.

-- A Flight Management Computer,
This dual CPU unit is the interface unit of the AFMS with the NAVCOM equipments and other aircraft systems (excluding flight control sensors & servos). This unit also has the ability for flight and engine performance calculations and voice synthesis.

(3) Electronic Horizontal Situation Indicator (EHSI) subsystem

This subsystem is a color CRT indicator system consisting of two sets of the following equipments.

-- Indicator
-- Symbol Generator
-- Mode Selector

2.3 System block diagram

A general block diagram of the AFMS is shown in Fig. 2 which indicates primary interfaces between subsystems of the AFMS and other avionics systems of the helicopter.

Data transmission between the primary components of the AFMS and the mission computer , the doppler radar , and the strap-down AHRSs is achieved through a MIL-STD-1553B multiplex data bus.

Data transmission between subsystems of the AFMS is achieved through RS-422 serial digital data links.

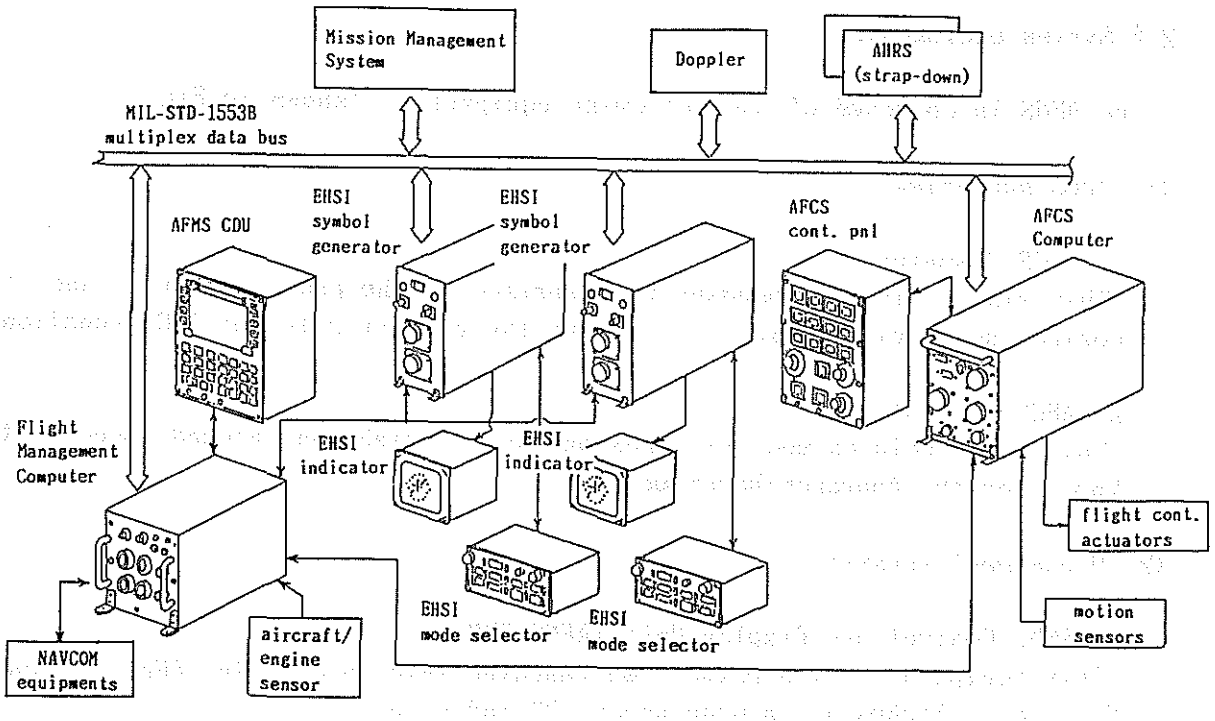

Fig. 2. General block diagram of the AFMS

3. Automatic Flight Control System

3,1 System architecture

A block diagram of the AFCS subsystem is shown in Fig. 3.

The purpose of this system is to enhance stability of the helicopter and provide autopilot capability.

The AFCS Computer plays the primary role for this function. The AFCS Computer controls the pitch angle of the main and tail rotor blades through 4 series servo actuators (SAS actuators) and 4 parallel servo actuators (trim actuators).

A simple analog SAS (Stability Augumentation System) amplifier is incorporated, and the dual-coil SAS servos receive servo command from both the digital AFCS Computer and the SAS amplifier. This architecture makes the stability augumentation function operative after first failure.

This architecture was selected in order to reduce cost and weight , also to provide dual redundancy of the critical components.

The autopilot functions are provided through rate-limited trim servos and can be overridden by manual control, therefore, flight safety is assured by a single system (single digital AFCS Computer).

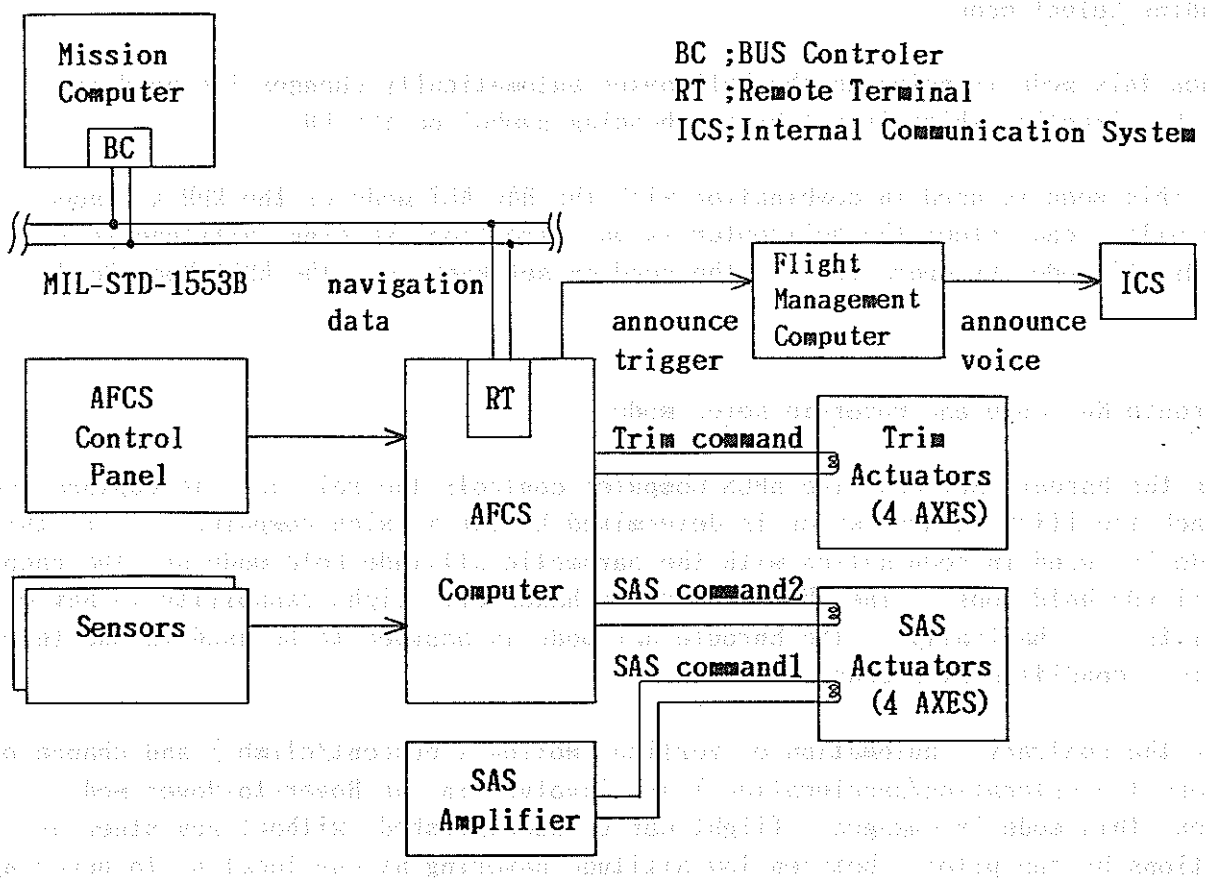

Fig.3. AFCS subsystem architecture

3.2 AFCS Functions

The AFCS functions of the AFMS are listed in Table 1. A Brief explanation of some of the modes is given in the following articles.

Basic Autopilot mode

The functions of this mode are;

-- attitude hold (pitch axis and roll axis)
-- heading hold (yaw axis)
-- airspeed hold (pitch axis)
-- automatic turn-coordination (yaw axis)

Pitch attitude is held in the low speed condition and airspeed is held in high speed condition.
The automatic turn-coordination function is active when the pilot is executing a turn manuever , otherwise the heading hold function is operating on the yaw axis.

Heading Select mode

When this mode is selected, the helicopter automatically changes its heading to the direction which is set by the heading symbol on the EHSI.

If this mode is used in combination with the BAR ALT mode or the RDR ALT mode, the pilot can steer the helicopter in any direction keeping altitude in the hands-off mode by operation of the heading set knob on the EHSI Mode Select Panel.

Enroute Nav mode and Hover-to-Hover mode

In the Enroute Nav mode the AFCS Computer controls the roll axis to capture and track the flight course which is determined by the mission computer. If this mode is used in combination with the barometic altitude hold mode or the radar altitude hold mode , the AFMS provides a hands-off flight capability to any way points. Basically , the Enroute Nav mode is assumed to be used in the level flight condition at a constant speed.

On the contrary , automation of vertical motion (descent/climb) and change of speed (acceleration/deceleration) are involved in the Hover-to-Hover mode. When this mode is engaged , flight can be accomplished without any steering actions by the pilots between low altitude hovering at one location to hovering at another location.
This mode is useful for Search and Rescue (SAR) operations.

Flight pattern of the Hover-to-Hover mode is shown in Fig. 4.

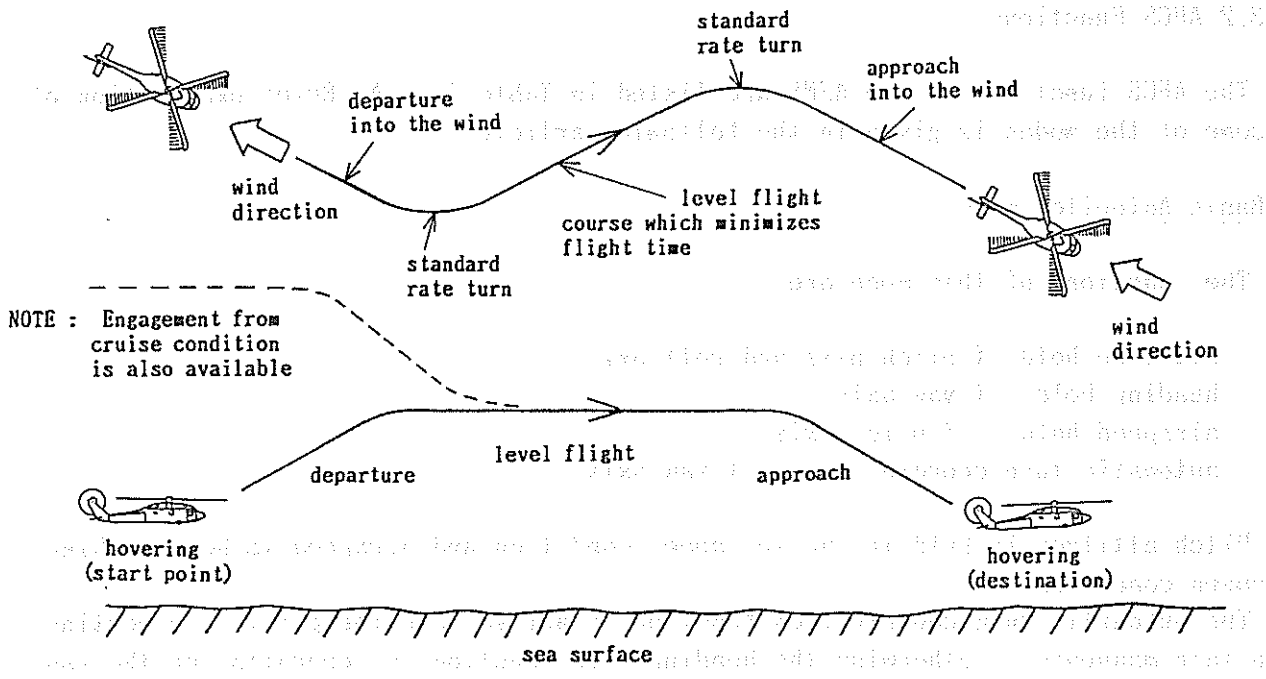

Fig. 4. Flight pattern of Hover-to-Hover mode

Table 1. List of AFCS functions

AFCS modes	functions
Basic Autopilots	- attitude hold - heading hold - airspeed hold - automatic turn coordination
BAR ALT	- pressure altitude hold
RDR ALT	- radar altitude hold
HDG SEL	- acquisition and hold of selected heading
AUTO APPR	- automatic approach to hover
AUTO DPRT	- automatic departure from hover to cruise
DPLR HVR	- selected ground speed and radar altitude hold
CREW HVR	- limited authority ground speed steering from crew station
ENRTE NAV	- roll steering coupled with navigation system
Hover-to-Hover	- full automatic flight from a hover point to other hover point

3.3 Monitoring function

The In-Flight Performance Monitor (IFPM) module of the AFCS software monitors sensor data , position feed back signals of servo actuators , and computer hardware.

If the IFPM detects a failure of a certain subsystem , the sensor signal from that system is replaced by the correct one or servo command is shut off automatically.

4. Flight Monitoring

The Flight Management Subsystem (Flight Management Computer and AFMS CDU) plays the primary role for this function, and the EHSI plays a secondary role.

A block diagram of the Flight Management subsystem is shown in Fig. 5.

The Flight Management Computer with flight management software calculates the helicopter flight performance such as the best flight speed (VBR and VBE) in cruise and torque margine in hovering , therefore enhancing the efficiency and safety of flight. The Flight Management Computer also automatically monitors the remaining flight hours.

Available items are listed in Table 2.

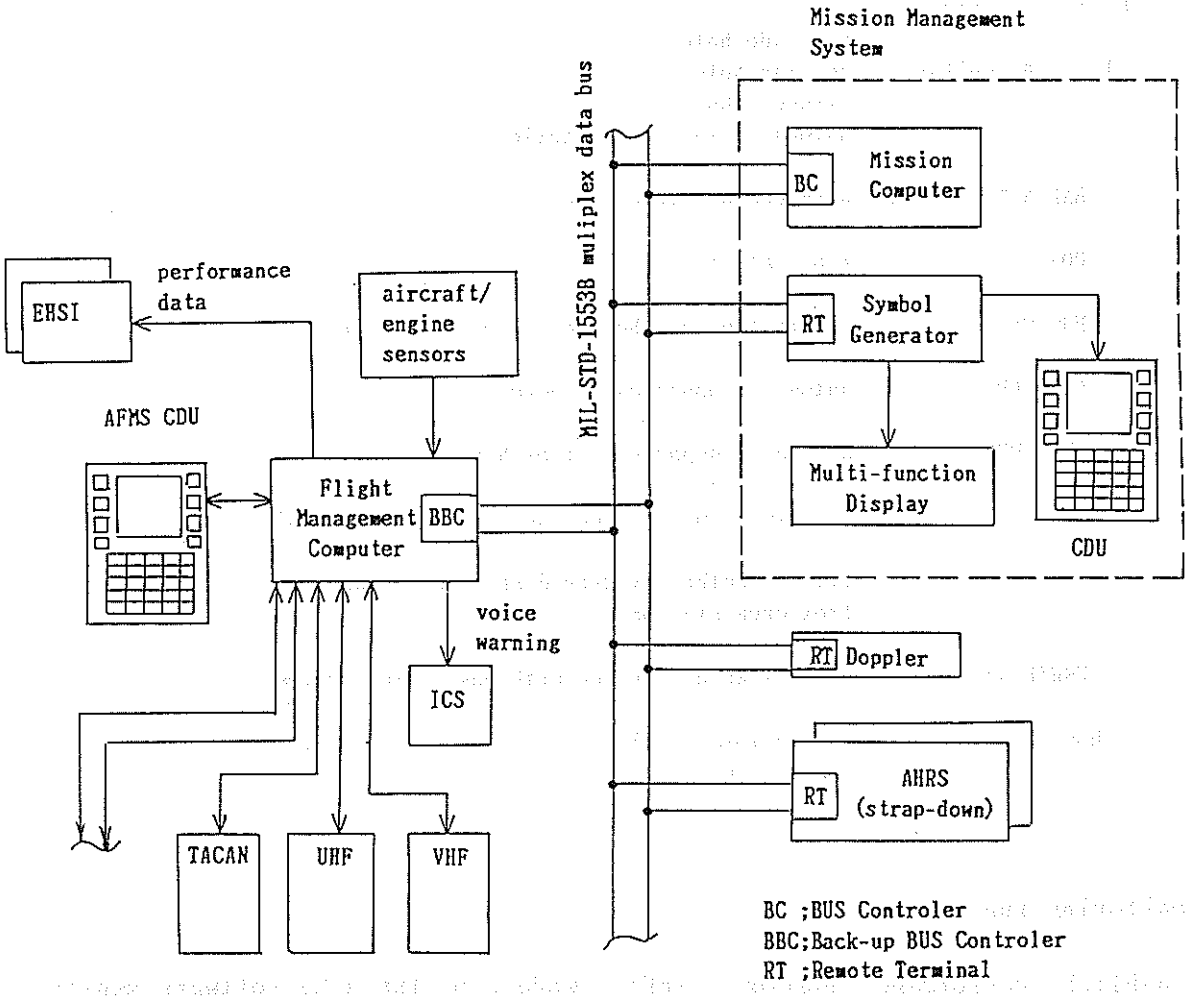

Fig.5 Flight Management subsystem architecture

The output of calculations are displayed on the CRT indicator of AFMS CDU. Items are selected by AFMS CDU switch operations. Data which requires constant monitoring is also able to be displayed in the lower corner of EHSI Display. Items to be displayed in the EHSI are selected by the AFMS CDU, and continue to be displayed disregarding change of the display mode by the EHSI. However, max. and min. speed of the OEI (one engine inoperative) conditions are displayed simultaneously on the EHSI display, when the OEI condition occurs.

Basically the Flight Management Computer calculates flight performance data according to the current weight of the helicopter , the flight altitude , the outside air temperature and wind data.

When performance predictions for other flight condition is needed , one can calculate them by substituting specific data via the number keys of AFMS CDU.

Table 2. List up of Flight Monitoring functons

Cruise Performance	Single Engine (OEI) Performance
- best range speed (Vbr) best endurance speed (Vbe) - max. range - max. endurance	- best range speed - best endurance speed - max. range - max. endurance
Hovering Performance	Status
- max. hover weight - hover weight margin - intermediate (military) engine power	- aircraft weight - c.g. station - distance to mother ship - remaining on-station time
Flight Check List	

5. Voice Warning / Announcement

The Voice Warning/ Announcement functions are involved in the Flight Management Computer. Voice warning capability enhances the crew recognition of emergency condition by supplying aural/ visual dual warnings.

Warning voices are generated when an emergency conditions occurs.
Examples of situations are as follows;
-- excessive droop of main rotor rpm
-- engine failure
-- fire
-- etc.

Warning voices are also generated when the remaining on-station flight hour is over.

When the Enroute Nav mode or the Hover-to-Hover mode of the AFCS function is engaged, a voice announcement comes on to announce the following events. It assures the crew that the automatic maneuver of aircraft is the result of normal operation of the AFMS and makes them ready for arrival at a way point.

-- start of turn
-- start to descent for hovering
-- approach and arrival at way points
-- etc.

A Priority decision and interlock algorism is incorporated in the Flight Management Computer software and voice synthesis circuit which interfaces with the engine/ rotor instruments and the caution system (including fire detecting system) is incorporated in the Flight Management Computer hardware.
As for voice announcement , the command is generated in the automatic guidance module of the software involved in the AFCS Computer and is transmitted into the Flight Management Computer via the inter-AFMS serial data bus. (c.f. Fig. 3)

When plural caution events occur simultaneously , caution voices are generated successively according to priority algorism incorporated in Flight Manegement Computer.
The most efficient cut-off frequency , sampling rate , tone , vocabulary , and number of iterations were determined through extensive recognition testings of several pilots under real helicopter cabin background noise conditions.

6. Integrated flight data display

EHSI subsystem plays the primary role for this function.

The EHSI display unit incorporates a color CRT which has adequate contrast ratio and automatic brightness control to provide sufficient visibility during day, twilight and night conditions.

Information to be displayed on the EHSI is as follows;
-- heading (magnetic/true)
-- bearing & distance of TACAN station
-- bearing & distance of a way point
-- ground speed & drift angle
-- wind speed & direction
-- flight performance data calculated by the Flight Management Computer
-- etc.

The information is displayed in several modes of display containing appropriate items for specific purposes.
Display modes are selected by mode switches on the EHSI Mode Selector Panel.

The automatic change of display mode coupled with AFCS is also available when the Enroute Nav mode or the Hover-to-Hover mode of AFCS function is engaged.
In this case , the appropriate display mode is selected automatically according to the flight situation.
(For example , the Doppler Hover mode is selected automatically at the begining of transition to hover.)
Manual mode selection has priority. The crew can change the display mode by the operation of the mode switch to override the automatic selection.

As for the attitude indicator , it was decided to use the mechanical equipment instead of developing an EAI (Electronic Attitude Indicator). This was the result of a cost/ performance trade-off study.

7. Integrated control of NAVCOM equipments

This function is carried out by the flight management subsystem (Flight Management Computer and AFMS CDU). (c.f. Fig. 5)

NAVCOM equipments to be controled by the AFMS CDU are as follows;
-- UHF
-- VHF
-- TACAN
-- Doppler
-- Strap-down AHRS
-- etc.

The AFMS CDU is the man/ machine interface of this function. Status of the NAVCOM equipments is displayed on the CRT and , the selection of operating modes and frequencies is done via the function switches.
The CRT indicator has adequate contrast ratio and automatic brightness control to provide sufficient visibility under day, twilight, and night conditions.
With regard to data input , the AFMS CDU has a validity check function so as to inform the crew that an invalid operation has taken place and also inhibit the data transmission to NAVCOM equipments.

The Flight Management Computer interfaces with the NAVCOM equipments. Data transmission with AHRS and Doppler is via a MIL-STD-1553B multiplex data bus.
The Flight Management Computer has dual CPU architecture to cover the processing task including performance calculations and to avoid the total loss of navigation and communication ability due to failure of one CPU.

8. Conclusion

The basic features of the Automatic Flight Management System (AFMS) developed by Mitsubishi Heavy Industries, Ltd. (MHI) have been described.

Because the reduction of crew work load is desirable for every kind of helicopter, we believe that this system has the potential for wide application.